Phase II Vehicle Development: Development of a Heavy Duty 0.5g/bhp-h NOx Refuse Hauler

Ken Murphy, Chun Tai

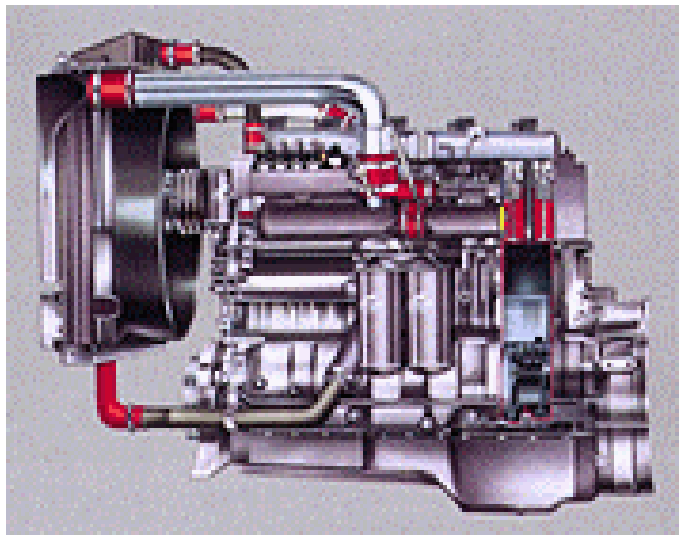
Mack Trucks, Inc.

Outline

- Objective
- Technology
- Synergisms
- Partners
- Schedule
- Challenges

Project Objective

- LNG (Current 12 Liter E7G, 325 hp, 1250 lb-ft) with a three-way catalyst, variable geometry turbo, and EGR powering a refuse hauler, targeted at 0.5 g/bhp.hr NOx and 0.01 g/bhp.hr particulate.



Technical Strategy

- Chemically Correct Combustion
  - No excess oxygen, can use automotive type of Three-Way-Catalyst
- High EGR Rates
  - A diluent to lower temperatures
- Three Way Catalyst
  - High conversion efficiency

Chemically Correct Combustion

- Automotive Type O_2 Sensor
  - Inexpensive
  - Reliable
  - On Board Diagnostics (OBD) capable (for correct feedback operation)
- Eliminates Problems with UEGO Sensor
  - Sensor sensitivity problems
  - Not OBD capable

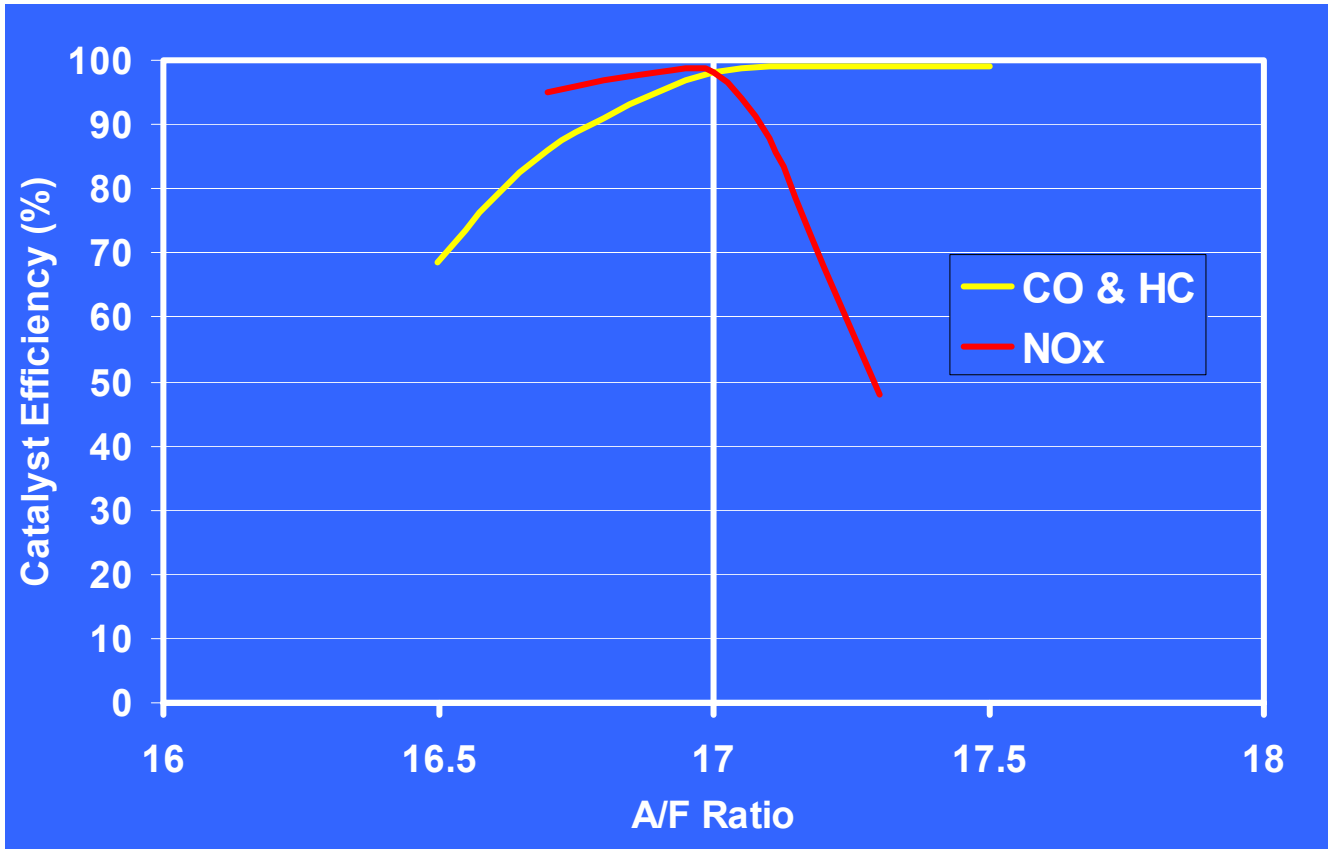
Exhaust Gas Recirculation

- Substitute EGR for Excess Air
  - Lower temperatures
  - Lower engine out NOx emissions
  - Lowers tendency to knock
  - Improves efficiency

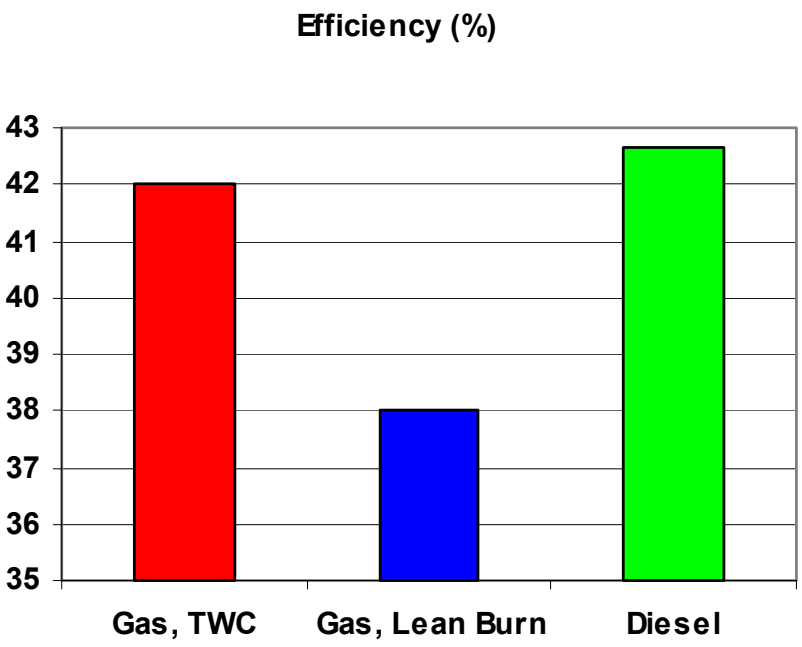
Three Way Catalyst

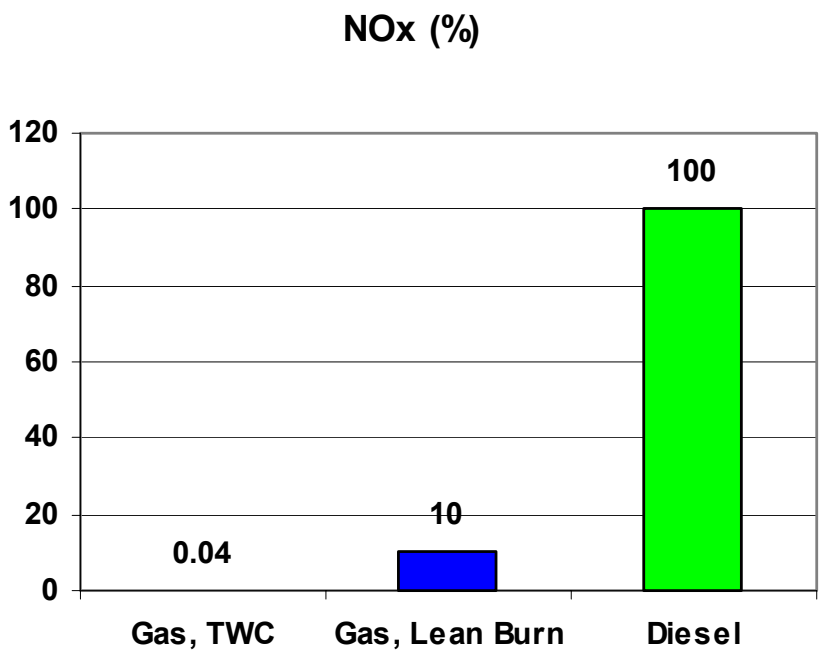
- High Efficiency
- Low Cost System
- Addresses HAPs
  - Including Formaldehyde
- Address Particulates
  - Particulates from natural gas engines are lube oil
  - Catalysts are designed to handle small amounts of lube oil

Three Way Catalyst

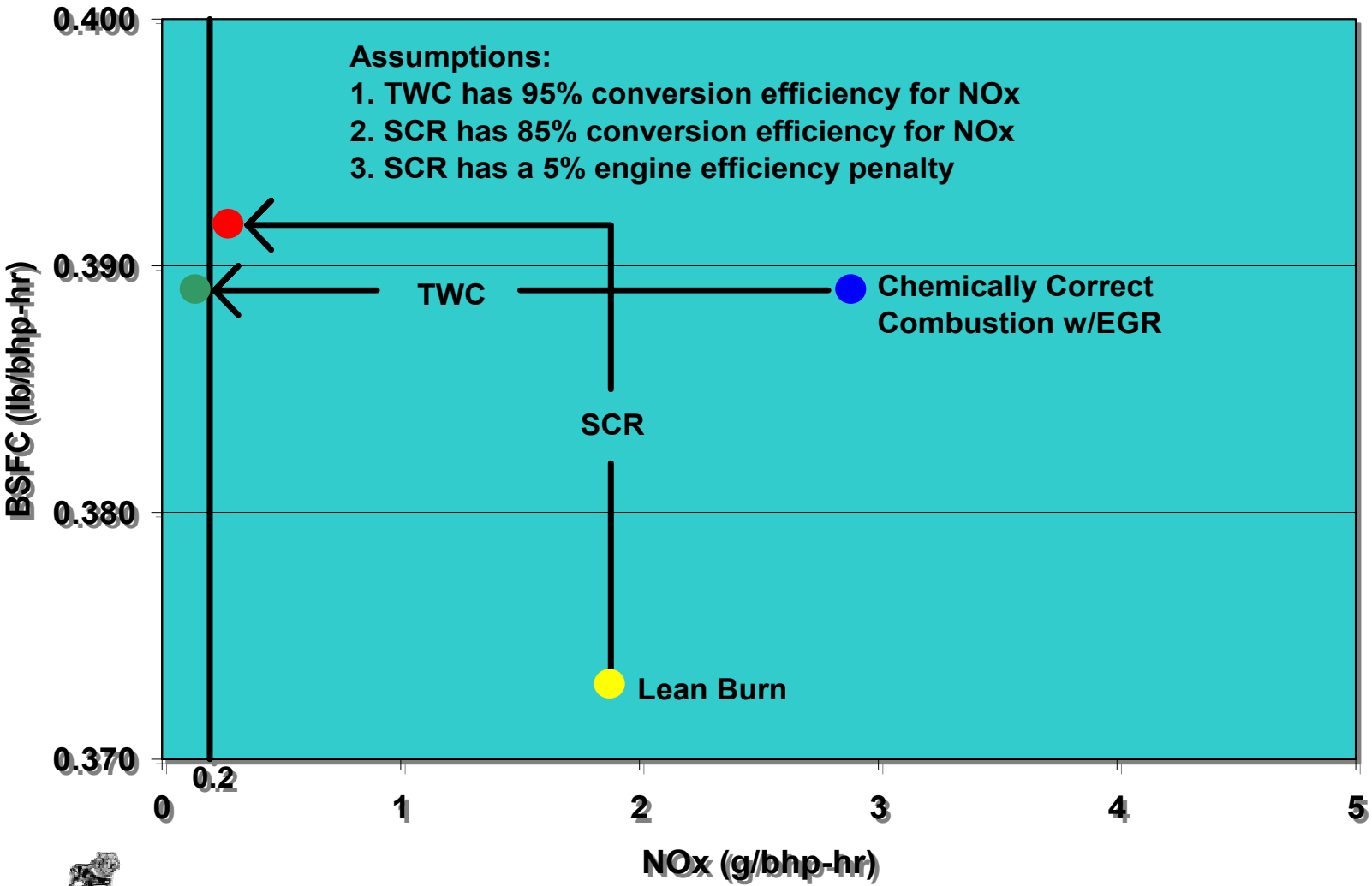


Efficiency and NOx Comparison (From SAE Paper 2000-01-2825)





Mack E7G Low NO_X Technology Assessment



The Mack Advantage

- Vehicle Engineering
  - Space for EGR system has been established
  - Space for an exhaust aftertreatment has been established
  - The E7G engine has been engineered into a refuse hauler and a line haul truck
  - Mack builds the engine and chassis

The Mack Advantage

The Mack Advantage

- Vehicle Engineering for Exhaust Aftertreatment

The Mack Advantage

- Technology can be transferred to refuse haulers
  - Waste Management is prepared to use landfill gas to power their refuse haulers

OEM Dedicated Natural Gas Vehicles From Mack Trucks

325 bhp CNG Demonstration Vehicle

325 bhp LNG Production Vehicle 2.5 g/bhp-hr NOx

325 bhp LNG Low Emissions Production Vehicle 2.5 g/bhp-hr NOx+NMHC (2.0 g/bhp-hr NOx)

Project Partners

- Subcontractor – Mack Trucks, Inc.
- Lower-Tier Subcontractors
  - Southwest Research Institute
  - Woodward Governor Company
  - Englehard Corporation
  - Donaldson Company, Inc.
  - Gas Technology Institute

Planning Chart

#	Task	Funding	Month 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	VGT Demonstration/Mapping	DOE/NREL																											
1	EGR Valve Evaluation	DOE/NREL																											
1	EGR Mixing/Distribution	DOE/NREL																											
1	EGR Cooling	DOE/NREL																											
1	Knock Limit	DOE/NREL																											
1	Compression Ratio	DOE/NREL																											
1	EGR Control (SwRI)	DOE/NREL																											
1	ERG Control (Mack)	DOE/NREL																											
1	Catalyst Evaluation	DOE/NREL																											
1	Component Design & Procurement	DOE/NREL																											
1	Prototype Software Development	DOE/NREL																											
1	Procure Prototype Parts	DOE/NREL																											
1	Build 2 Engines	DOE/NREL																											
1	Durability Testing	SCAQMD																											
1	Emissions Testing to establish D.F.	SCAQMD																											
2	Build 2 Vehicles & Install Engines	SCAQMD																											
3	Road Test Vehicles at Mack	SCAQMD																											
3	Datalogger - develop/install/take data	SCAQMD																											
3	Vehicle "Field Demonstration"	SCAQMD																											
3	SwRI Support of "Field Demonstration"	SCAQMD																											
3	Emissions Testing of Field Adjustments	SCAQMD																											
4	Chassis Dynamometer Testing	DOE																											
5	Engine Certification	Mack																											

Challenges

- Catalyst Degredation
  - Similar problems as with the automotive industry
- EGR System
  - Similar problems as with 2002 diesel engines
  - Transient control